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AUGMENTATION AWARDS FOR SCIENCE AND ENGINEERING TRAINING (AASERT) FY 96

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Georgia Institute of Technology

Georgia Tech Research Institute
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Augmentation Awards for Science and Engineering Research Training (AASERT) FY99

Background

The Augmentation Awards for Science and Engineering Research Training (AASERT) program is designed to increase the number of high-quality scientists and engineers educated as part of Defense-sponsored research. The award would serve as augmentation to a Department of Defense (DOD) contract by supporting additional graduate students, which would not normally be supported by the contract.

In October 1994, Georgia Tech was awarded a three-year contract (N00014-95-C-0007) with two-year follow-on options for the development of a new approach in submarine sonar systems. Two programs were established; a passive sonar capability referred to as CAVES (Conformal Acoustic VElocity Sonar) and an active capability referred to as CACTISS (Conformal Active Sonar System). Both programs utilize the submarine hull's structural acoustics and submarine decoupling coatings under development by the Navy. Due to the success of the CACTISS program, it has transitioned to full scale testing and is no longer considered a basic research effort at Georgia Tech. The CACTISS program has matured to quarter scale testing at the Intermediate Scale measurement System at Lake Pend Oreille, Idaho. The Office of Naval Research (ONR) program manager is Dr. Geoffrey Main. This CAVES/CACTISS contract was selected as the parent award.

In discussions with the ONR program manager and Program Executive Officer/Undersea Warfare/Advanced Sonar Technology Office (PEO/USW/ASTO), it was decided to stress the measurement technologies necessary to advance the coatings and small-scale measurement program. This represents a departure from the ASSERT proposal where one student was to study the elimination of hull self-noise from sensors. Subsequent full-scale data determined that the self-noise was not as large as originally anticipated and, therefore, not as relevant. The graduate student's thesis was then structured to support the small-scale program.

Summary of thesis research

Three students (Thomas Logan, Brain Prasse, and David Daughtrey) were supported under this ASSERT grant. In the original ASSERT proposal, Logan was proposed to complete his Ph. D., however, he decided to seek permanent employment after his Masters Degree. Funding then became available to support a third student. Logan received his Master of Science in Mechanical Engineering in September 1997 and subsequently completed all requirements for the Ph. D. less the dissertation in December 1998. Prasse and Daughtrey will graduate with Master of Science degrees in Mechanical Engineering in August 1999.

Tom Logan's research involved the study of forward scattering by fluid-loaded elastic structures. Brain Prasse's research involved the calibration, automation, and accuracy of bistatic scattering measurements made in the Georgia Tech Acoustic Tank Facility. They developed a nearfield measurement system (NFMS) consisting of a nearfield transmit array (NFTA) and a synthetic aperture nearfield receive array (NFRA) to study the study the radiation and scattering of sound by fluid-loaded objects. This system is located in an existing 33,000 gal freestanding cylindrical tank facility. The physical principles that motivated the development of the NFMS was work previous performed by Lee Van Buren of USRD in nearfield calibration arrays. The basic concept involved is that the appropriately shaded voltage response of the NFRA can be made to be directly proportional to the farfield directivity of the scattering or radiating object.

The NFTA is made up of 34 line elements consisting of 26 small reciprocal transducers. Each line element has fixed real shading. The NFRA consists of a single line element of the same type that comprises the NFTA. The NFTA is amplitude shaded to produce a plane wave field within a cubic volume in front of the array. The scattering object is placed in this volume and the scattered pressure field is received by the NFRA. The individual transducers of the NFRA are also amplitude shaded and summed by external electronics. The aperture for the NFRA is formed synthetically by moving the NFRA cylindrically around the scattering object using a precision position system. Upon acquiring data on the NFRA, the farfield pressure field is determined by appropriately

shading the individual measurements made by the NFRA using a digital data acquisition system.

In support of the NFMS, Logan has developed an array of software tools. He has developed models of the pressure field produced by the NFTA and models of the time-domain signals produced by the NFTA and received by the NFRA. He has also developed software to compute the optimal shading coefficients for the NFTA and NFRA as well as process data from the NFMS.

Prasse built a synthetic aperture nearfield receive array (SA-NFRA) for scattering data. This array consists of a line of 26 hydrophones that is used to scan the field around a scattering object. This receive array was built by means of modification of a spare transmit line from the NFTA. The receive array has 13 channels of output, each of which is shaded and contributes to an overall summed waveform. In order to shade each of the 13 channels, electronic circuits consisting of potentiometers were built. The summing of the 13 weighted waveforms was made possible by a summing circuit consisting of an OP27 amp, which was also constructed.

The entire data acquisition system is automated. The receive array is fastened to an XY positioner. The positioner allows a complete circular scan of a scattered field around an object. The entire system is driven by LabVIEW, which communicates with the positioner motors over RS232, and issues commands to a dynamic signal analyzer data acquisition analog-to-digital (A/D) card. LabVIEW will move the positioner to a desired location, and then acquire data. This process is repeated until an entire circular scan is made around the scattering object.

Measurements of the pressure field produced by the NFTA were made. Preliminary amplitude and phase uniformity measurements show the field produced by the NFTA has amplitude uniformity within 0.5 to 1.5 dB and a phase uniformity of 5 to 10 degrees.

Measurements of small pressure-release sphere were made with the NFMS. Preliminary scattering measurements of pressure-release objects demonstrate that the system is viable for making forward scattering measurements for Mr. Logan's experimental work in forward scattering. Additionally, the NFMS can make backscattering and bistatic scattering measurements.

To further improve the performance of the NFMS and enhance the ability to make useful forward scattering measurements, Mr. Logan is investigating the possibility of individually driving each element of the NFTA. The principal goal of this effort is to improve the field uniformity of the NFTA and to mitigate diffraction effects from the edges of the NFTA.

The work performed by David Daughtrey involved the development of an underwater Laser Doppler Vibrometry (LDV) system with the unique ability to operate in the high-radiation case (that is, in the presence of underwater sound). The project was a continuation and expansion of work done previously at Georgia Tech in the area of LDV development. The goal of the project was an LDV system capable of making out-of-plane vibration measurements on a submerged, diffusely reflecting surface in the presence of underwater sound. The primary motivation for the development of such an LDV system was for use in surface motion studies of the compliant coatings used in the CAVES/CACTISS program. However, such a system would be useful for studying any fluid loaded structure that is either radiating a significant acoustic field or is moving due to an incident acoustic field.

Experience in LDV gained at Georgia Tech had shown that several effects induced by an underwater acoustic field must be accounted for if accurate measurements are to be made. Briefly, these effects were related to phase modulations induced in the light path rather than by the vibrating surface and acoustical scattering by the LDV probe and its positioning system. Thus, in order for LDV to be used in the high radiation case, the system needed to have several unique characteristics that enabled it to eliminate or account for the error sources. The general plan for the system was to allow it to make measurements as close as possible to the moving surface while keeping its size to a minimum to reduce its scattering effects. Additionally, it was proposed to utilize common-mode rejection, a technique that seeks to eliminate environmental noise sources by having them act simultaneously on both the signal and reference legs of an interferometer.

To implement this plan it was proposed to send and receive light through one single-mode polarization-maintaining fiber. This would eliminate the need for complicated alignment mechanisms on the probe head and would thus allow for a probe

of minimal size. However, the poor coupling efficiency of single-mode fibers along with the poor reflectivity of a diffuse surface required a special optical setup that could isolate the light returning from the moving surface from all other competing backreflections. The major portion of the work undertaken by Daughtrey concerned the implementation of this type of optical setup. The work began with a study of the reflection characteristics of optically diffuse surfaces. Knowledge of the polarization state and directivity of the reflected light, in particular, were needed for design of the optical setup. The work continued with an examination of the light gathering abilities of single-mode fiber as well as an extensive examination of the use of polarization isolation techniques to eliminate all unwanted back reflections. Issues such as laser coherence length were examined and dealt with and the optical setup was eventually completed. A probe of minimal size was built and a FM demodulation scheme was selected and implemented. The result was an LDV system capable of operating in air that sent and received light down one single-mode fiber and could operate on a minimal amount of backreflected light (under a microwatt). Additionally, the system required a laser source of modest power and relatively minimal cost (a 10 mW HeNe laser).

When the requirement was met to have a system able to make measurements close to a surface and of minimal size, the work turned to adapting the system for use underwater. The work had two goals. The first was to evaluate the scattering effects of the probe. In other words, determine whether its "minimal" size was minimal enough. The second goal was to evaluate the usefulness of common-mode rejection. This work included a study of the modulation effects of acoustic waves on optical fibers.

Summary

The AASERT grant supported three graduate students who successfully completed their Masters Degrees in Mechanical Engineering while significantly contributing to the enhancement of a state-of-the-art measurement facility at Georgia Tech. This measurement facility will be used to support Navy research and graduate education in the future.

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This report documents in summary format the research performed under the AASERT grant N00014-96-1-1018. The AASERT "parent" grant is the ONR contract for the Conformal Acoustic Velocity Sonar (CAVES). Three graduate students were supported by this grant and they performed research in nearfield array measurements and Laser Doppler Vibrometry (LDV) in the presence of a large acoustic excitation.

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